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Reports
Howe,
G. E.

PROJECTED YIELD INCREASES FROM TREE IMPROVEMENT: RECOGNITION IN FOREST PLANS

by

G.E. Howe[1]

and

Fred D. Hodgeboom[2]

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[1]Regional Geneticist, TCFPM.
[2]Timber Management Plannner, Flathead National Forest.

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PURPOSE

The purpose of this document is to describe the rationale and biological foundation for projecting timber volume increases from the Northern Region's tree improvement program. We also offer recommendations for how these projected increases should be considered in Forest Plans.

HISTORY

Program Documents

In 1986, the Regional Forester endorsed an accelerated tree improvement program, based on a 1985 comparison of several alternative program levels compared in The Forest Tree Improvement Program for the Northern Region---Alternative Levels (FTIPNR)[1]. The Region had developed a comprehensive tree improvement program in the early seventies on the strength of analyses documented in The Forest Genetics Program for the Northern Region in 1973, which showed both yield and economic benefits to producing, planting growing and harvesting genetically improved trees on Northern Region National Forests. By the early eighties, intervening legislation---principally the RPA and NFMA---suggested we take a fresh look at the tree improvement program. We evaluated the program for its biological foundation and its responsivness to legislation. Based on these criteria, was the program too big, too small or just the right size? What changes in direction were needed? From this review of legislation and policy, in FTIPNR, we formulated a new mission statement for the program:

> The mission of the Northern Region's tree improvement program is to increase the yields of wood on appropriate lands through forest tree improvement, and avoid genetic losses in all forest management treatments...consistent with regulation and budgets.

The avoidance of genetic losses in forest management treatments received added emphasis in the FTIPNR, but this component of the tree improvement program is not the subject of the current report. The subject of the current report is the analysis of the selective breeding program, that is, the production, planting, growing and harvesting of genetically improved trees.

The FTIPNR Analyses

Procedures. The FTIPNR addressed the question, "On which Northern Region National Forest lands would the planting, growing and harvesting of genetically improved stands forecast a higher present net value (PNV) than regeneration alternatives?" All investments prior to 1983 were considered sunk costs.

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[1] By Howe, G.E. and T.L. Raettig. 1985. USDA Forest Serv. Northern Region. Missoula. 56 pp.

To answer this question, we projected[1] the growth, yield and present net value (@ 4 percent discount) of a stand of woods-run trees to a stand of genetically improved trees growing on the same site for each of ten sites across the Region. The sites were selected to represent typical habitat types and productivites for lands on which timber production was to be emphasized. We ran 12 such paired comparisons on the ten sites. The woods-run (unimproved) alternative in every case was the young stand actually growing on the site in the early eighties; the improved alternative started with a stand of the same age, stocking and species composition, but was grown by the Prognosis model at an accelerated rate (with two exceptions[2]) to reflect the predicted genetic gains. For these 12 analyses, only lands already scheduled (in Forest Plans) for planting were considered.

We translated predicted genetic gains (from our own and similar progeny tests) into into growth multipliers in the Prognosis model[2]. These multipliers were 5 percent for diameter growth (for all species) and ranged from 9 percent to 13.5 percent for height growth, depending on species. We translated the projected costs for our breeding program into cost per acre planted with genetically improved trees, and this cost ranged from $3 to $9 per acre above the cost of planting woods-run trees (in only one of the 12 comparisons did the added cost per acre exceed $8). The other projected costs entered into the analyses (e.g., persistent with similar estimates being used in R-1 at the time, as were estimates of projected revenues. Rotation was considered to be at 95 percent of culmination of mean annual increment (CMAI), and the PNV comparisons assumed an infinite series of rotations.

In a set of ancillary comparisons, we addressed the question, "are there lands on which the planting, growing and harvesting of genetically improved trees will project a higher PNV than a stand originating from natural seedfall?" To answer this question, we reran the comparisons for a subset of the sites described above, but assumed that the unimproved stand in each case had originated from natural seedfall.

Following these site-specific analyses, we extapolated the site-specific results to all similar lands, respectively, in the Region. These extrapolations, however, did not account for effects on forest regulation.

Results. In all comparisons, the genetically improved alternative showed a higher yield than the unimproved alternative if rotation lengths were equal.

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[1]Using the Intermountain Station Prognosis Model.

[2]These two comparisons were for blister rust-resistant western white pine growing on sites typical of WP sites in the Northern Region. The benefits for planting, growing and harvesting blister rust-resistant WP accrue from reduced mortality and a higher WP component in the stand, rather than from increased growth of the improved WP trees compared to unimproved WP trees, so growth multipliers were not entered into the improved alternative for these two comparisons.

But for six of the comparisons, 95 percent CMAI occurred at least one decade earlier for the genetically improved alternative; for one comparison (on the most productive site in the analyses), CMAI occurred two decades earlier. The difference in rotation length, of course, would be cumulative---after one rotation the manager would be 20 years ahead with genetically improved trees; after two, 40 years ahead; after three, 60 years; etc. The estimated added yields over several rotations were significant.

Yield increases for the improved alternatives (vs the unimproved) ranged from 4.5 percent to 31.7 percent (for equal rotations). The majority were in the mid to high teens, considering all 12 comparisons.

In all the principal comparisons, PNV for the genetically improved alternative was higher than for the unimproved alternative, with one exception in which PNVs were equal (a very low productivity site requiring planting under a shelterwood). In the ancillary comparisons of planting improved trees vs naturally regenerated stands, one comparison (and only one) showed a higher PNV for planting improved trees. This was on a high productivity site in northern Idaho (many such acres are scheduled in current Forest Plans to be naturally regenerated!).

When these site-specific analyses were extrapolated to all other similar lands, the added yields amounted to 366 MMBF per year for the Region after the mid-21st Century, compared to planting only woods-run stock, a 17.6 percent increase (2450 vs 2084 MMBF). But these extrapolations did not take into account the program's effects on forest regulation and therefore are likely quite conservative.

THE FORPLAN RUNS

Introduction

To overcome the shortcomings of the extrapolations described in the preceding sections, the senior author of the FTIPNR (Howe) collaborated with Aurelia ("Bea") Harris (see Appendix 1) and Fred Hodgeboom to employ the FORPLAN model to estimate the effects of planting, growing and harvesting genetically improved stands on a Region 1 National Forest. The Forest selected for this pilot project was the Flathead because of its substantial timber management and planting program and because three of the ten sites selected for the site-specific analyses described in the preceding sections were Flathead sites. Thus, we already had an indication that the planting, growing and harvesting of genetically improved stands on this Forest would be economically favorable. It was our intent to develop a procedure for FORPLAN for comparing the planting, growing and harvesting of genetically improved stands with unimproved.

Rationales and Assumptions

There are several interacting factors included in FORPLAN economic analyses. As volume per acre increases, logging cost per acre decreases, thus increasing the stumpage value of a unit of volume. The average diameter of the trees and the tree species determines the value of products which can be produced from a

unit of volume. Genetically improved planting stock produces larger trees faster, resulting in higher value wood sooner than woods-run stock. The cumulative effect on the discounted stumpage value (per acre) of increased diameter and height growth on high-value species and increased volume (per acre), by time period, can be evaluated against the reforestation investment cost in FORPLAN.

How was FORPLAN to recognize genetically improved trees? FORPLAN requires timber yield and associated economic tables to generate timber harvest schedules with volume and value estimates. Regenerated timber yield tables in FORPLAN represent the forest-wide average yield for the range of natural stocking levels and productivities represented in each timber working group and analysis area growing sites. Prognosis could have been used to generate "genetic" ("improved") yield tables for all timber working groups in FORPLAN, but this lengthy process (projecting many individual stands using a growth multiplier in Prognosis, then averaging the results in a FORPLAN yield table) would not improve the confidence limits of the yield estimate. Thus we simply increased the current FORPLAN regenerated yield tables for managed stands by 15 percent across the board (see Appendix 1) to create a comparable set of genetic yield tables. The 15 percent yield increase is consistent with the average results of the majority of the 12 site-specific analyses described in the foregoing sections as well experienced results of tree improvement programs documented in the literature (see Appendix 8 in FTIPNR). Tree improvement programs documented in the literature have resulted in diameter growth averaging 5 percent above woods run stock (FTIPNR). Woods-run diameters were increased by 5 percent in the improved FORPLAN yield tables.

How was FORPLAN to recognize the cost of tree improvement? In the FTIPNR, we had estimated that the cost of our tree improvement program, translated into added planting stock cost per acre for planting "genetically improved trees, rarely exceeded $8.00 (see preceding sections). A set of economic tables associated with the improved yield tables were created by adding $8.00/acre to the regeneration costs for the economic tables which employed planting using normal stock on the same analysis area (see Appendix 1). The discount rate used in FORPLAN was 4 percent.

Running FORPLAN

The PNV Benchmark FORPLAN data set was selected to test the "genetic" yield tables and economic data. The economic benchmark has fewer constraints to model multiple use objectives (recreation, wildlife, visuals, etc.) which could interact to skew economic analysis of the "genetic" yield data.

The basic strategy was to add an improved stock regeneration prescription option to compete on every tentatively suitable analysis area with the original range of management intensity prescriptions (thinning vs. no thinning etc.). The original range of management prescriptions included only natural regeneration and/or woods run planting stock regeneration management practices. In this way FORPLAN could calculate all the alternative outputs, costs and returns for an increased range of regenerated stand management intensity prescriptions. FORPLAN could then schedule the amount of planting of improved stock each decade on the sites which would optimize total economic

returns in the future, considering the optional $8 per acre reforestation investment vs. the future value of the increased yield. The optimal schedule was calculated subject to timber regulation and other legal constraints included in the FORPLAN model.

Results

The FORPLAN run with the genetically improved stock forecast a PNV $3247 MM dollars higher than the unimproved run, and a long-term sustained yield 47 MMCF higher (322 vs 275 MMCF) (Appendix 1). These results accounted for the effects on forest regulation of planting, growing and harvesting improved trees subject to the single economic objective of maximizing theoretical returns to the US Treasury.

The analysis indicated that during the first five periods, investment in genetically improved stock waseconomically feasible on more than half of all the regeneration harvest acres on the Flathead National Forest. Most of the sites scheduled for "genetic" stock were high productivity sites (potential productivity greater than 85 cu. ft. per acre/yr.). It should be noted that this analysis only analyzed the optimal use of "genetic" stock which would theoretically maximize total economic returns to the U.S. Treasury. If additional multiple-use objectives or indirect economic effects of increased timber supply from a given land base were considered, the amount of "genetic" investment would vary from these results.

DISCUSSION

The authors of the FTIPNR felt that the site-specific analyses did a reasonable job of comparing the production, planting, growing and harvesting of genetically improved trees against unimproved on the same site, but not a good job of extrapolating those results to all other similar sites. The method used to extrapolate the results did not account for the tree improvement program's effect on forest regulation. FORPLAN is designed to account for the effects on forest regulation of changes in management practices, such as the substitution of improved planting stock for woods-run. We believe the outcome of the pilot project described in the current report is a reasonable portrayal of what can be expected in planting, growing and harvesting genetically improved trees on a Northern Region National Forest.

The Region's tree improvement program is designed to produce genetically improved stock sufficient to plant all lands scheduled for planting and on which the planting, growing and harvesting of improved stands will forecast a higher PNV than woods-run planting stock. Our FTIPNR analyses suggested that such lands would represent nearly 100 percent of our scheduled planting program. The program will also produce enough improved stock to plant the lands currently scheduled for natural regeneration but which may be more economically planted with improved trees (as judged by PNV), should the Forests choose to do so.

Forests may choose to benefit from the increased yields from tree improvement in either of two ways. One option would be to plant, grow and harvest genetically improved trees on virtually ALL lands scheduled to be planted (plus some scheduled for natural regeneration), including lands of modest productivity.

This option would increase yields in the late 21st Century for Northern Region National Forests, compared to current. This scenario is the one described by the FTIPNR. The second option would be to plant, grow and harvest genetically improved trees only on the Region's most productive timber lands. We have not quantified the yield consequences of this option, but one could speculate that yields might remain about the same as current or increase.. This option might be regarded as attractive in its potential for meeting timber goals from fewer acres, thus reducing the pressure to produce timber on less productive lands that might be in demand for other uses. In either case, FORPLAN allows the Forest to look at the alternative strategies for deploying genetically improved planting stock.

RECOMMENDATIONS

All Northern Region National Forests should evaluate the effect of planting, growing and harvesting genetically improved trees, using the FORPLAN procedure described in this report. Forests should determine which lands are more favorably planted with genetically improved trees than by regeneration alternatives, including natural regeneration, while meeting other resource objectives, based on comparative PNVs. Wherever these analyses favor the planting, growing and harvesting of genetically improved trees, the Forests should schedule those lands to be planted with the improved stock and reflect the added yields in the next generation of Forest Plans.

The RO should prepare the appropriate directives reflecting these recommendations.

APPENDIX 1

The FORPLAN Results for the Flathead National Forest Using Genetically Improved Stock Alternative

THE FORPLAN RESULTS FOR THE FLATHEAD NATIONAL FOREST USING GENETICALLY IMPROVED STOCK ALTERNATIVE

by

Aurelia B. Harris[1]

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[1]Economist, Mensuration and Systems Development, WO---Ft. Collins.

FORPLAN was run for the Flathead using genetically improved stock as alternative regeneration prescriptions. Regenerated yield tables were increased by 15 percent over the original yield tables to model for the improved stock's increased growth rate[1]. Increased cost of planting genetically improved stock was estimated at $8 per acre[2].

The comparison of preferred alternatives without genetically improved stock and with genetically improved stock were included in the analysis. The results were:

	Original Run	Improved Stock Run
Present Net Value	393,630 $MM	396,877 $MM
Long Term Sus-yield	275 MMCF/decade	322 MMCF/decade
Volume Harvested in decade:	----------MMCF----------	
1	252	252
2	252	252
3	292	293
4	350	352
5	420	422
6	504	507
7	404	445
8	323	356
9	258	422
10	252	338
11	252	270
12	252	252
13	252	267
14	252	304
15	252	365
	4567	5097

From the FORPLAN model the Forest set a floor of 252 MMCF to be harvested each decade to maintain consistency in the supply of timber that would be cut annually. Using a 4 percent discount rate, PNV increased approximately $3,247 MM when the tree improvement alternative was included in the model and long-term sustained yield increased 47 MMCF when the proposed genetics alternative was in place.

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[1] Howe, G.E., concludes that a 15 percent increase is a reasonable estimate, based on the analyses in the document cited in footnote 2, below.

[2] See: Howe, G.E. and T.L. Raettig. 1985. The Forest Tree Improvement Program for the Northern Region. USDA Forest Serv. Northern Region. 56 pp.

Regeneration records:

Decade 1	Original Run	Improved Stock Run
Total Acres Regenerated	72,382	72,383
Acres Planted with Improved Stock	0	45,272
Decade 2		
Total Acres Regenerated	52,600	52,600
Acres Planted With Improved Stock	0	35,003
Decade 3		
Total Acres Regenerated	60,958	61,551
Acres Planted With Improved Stock	0	35,671
Decade 4		
Total Acres Regenerated	68,397	68,225
Acres Planted With Improved Stock	0	28,758
Decade 5		
Total Acres Regenerated	77,489	79,580
Acres Planted With Improved Stock	0	35,954

The comparison of the regeneration alternatives (with and without genetically improved stock) shows that planting genetically improved stock does increase PNV as well as increase the long-term sustained yield for the Forest. Due to increased long-term sustained yield capacity, harvest can be increased beginning in decade 3 over identical management using unimproved planting stock and natural regeneration. The analysis indicates that during the first five periods, investment in genetically improved stock is economically feasible on more than half of all the regeneration harvest acres. It should be noted that this analysis only analyzed the optimal use of genetic stock which would theoretically maximize total economic returns to the U.S. Treasury. If additional multiple-use objectives or indirect effects of increased timber supply from a given land base are considered, the amount of genetic investment would vary from these results.